

## CLAIMS

What is claimed is:

1. A method for providing predictive maintenance of a device, comprising the steps of:

modeling as a time series  $x_n$  of a discretely sampled signal representative of  
 5 occurrences of a defined event in the operation of said device, said time series  $x_n$  being  
 modeled as two-state first order Markov processes with associated transition probabilities  
 $p(i|j)$ , wherein state 1 applies when the number of said occurrences exceeds a certain  
 threshold  $T$ , and state 0 applies when the number of said occurrences falls below said  
 certain threshold  $T$ , being represented as:

$$S_n = \begin{cases} 0 & \text{if } x_n \leq T \\ 1 & \text{if } x_n > T \end{cases}$$

wherein said transition probability  $p(i|j)$  is the switching probability from state  $j$  to state  $i$ ,  
 that is, the probability that  $S_n = i$  given that  $S_{n-1} = j$ , being a total of 4 transition  
 probabilities;

computing said four transition probabilities the last  $N$  states  $S_n$ , where  $N$  is a  
 15 predetermined number;

conducting a supervised training session utilizing a set of  $J$  devices, which have  
 failed due to known causes and considering the two independent probabilities  $p(1|1)$  and  
 $p(1|0)$ , said training session comprising:

computing the two-dimensional feature vectors  $f_i = \{p(1|1), p(1|0)\}_i$  for the  
 20 initial  $M$  windows of  $N$  scans,

computing the two-dimensional feature vectors  $f_f = \{p(1|1), p(1|0)\}_f$  for the  
 final  $N$  number of scans,

plotting a scatter-diagram of all 2D feature vectors  $(f_i)_n$  and  $(f_f)_n$ , ( $n = 1 \dots J$ ), and

deriving a pattern classifier by estimating the optimal linear discriminant which separates the two foregoing sets of vectors; and

applying said classifier to monitor the persistence of occurrences of said defined event in the operation of said device.

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2. A method for providing predictive maintenance of a device as recited in claim 1, including the steps of:

updating said transition probabilities at each scan are updated; and

constructing the feature vector  $f = \{p(1|1), p(1|0)\}$  constructed.

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3. A method for providing predictive maintenance of a device as recited in claim 2, including the step of:

providing a warning of imminent failure of said device if  $f$  falls into a region of said classifier corresponding indicating such failure prediction.

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4. A method for providing predictive maintenance of an X-ray tube, comprising the steps of:

modeling as a time series  $x_n$  of a discretely sampled signal representative of occurrences of arcing in the operation of said tube, said time series  $x_n$  being modeled as two-state first order Markov processes with associated transition probabilities  $p(i|j)$ , wherein state 1 applies when the number of said occurrences exceeds a certain threshold  $T$ , and state 0 applies when the number of said occurrences falls below said certain threshold  $T$ , being represented as:

$$S_n = \begin{cases} 0 & \text{if } x_n \leq T \\ 1 & \text{if } x_n > T \end{cases}$$

wherein said transition probability  $p(i|j)$  is the switching probability from state  $j$  to state  $i$ , that is, the probability that  $S_n = i$  given that  $S_{n-1} = j$ , being a total of 4 transition probabilities;

5 computing said four transition probabilities the last  $N$  states  $S_n$ , where  $N$  is a predetermined number;

conducting a supervised training session utilizing a set of  $J$  X-ray tubes, which have failed due to known causes and considering the two independent probabilities  $p(1|1)$  and  $p(1|0)$ , said training session comprising:

10 computing the two-dimensional feature vectors  $f_i = \{p(1|1), p(1|0)\}_i$  for the initial  $M$  windows of  $N$  scans,

computing the two-dimensional feature vectors  $f_f = \{p(1|1), p(1|0)_f\}$  for the final  $N$  number of scans,

plotting a scatter-diagram of all 2D feature vectors  $(f_i)_n$  and  $(f_f)_n$ , ( $n = 1 \dots J$ ), and

15 deriving a pattern classifier by estimating the optimal linear discriminant which separates the two foregoing sets of vectors; and

applying said classifier to monitor the persistence of occurrences of said arcing in the operation of said X-ray tube.

20 5. A method for providing predictive maintenance of an X-ray tube as recited in claim 4, including the steps of:

updating said transition probabilities at each scan are updated; and

constructing the feature vector  $f = \{p(1|1), p(1|0)\}$  constructed.

25 6. A method for providing predictive maintenance of an X-ray tube as recited in claim A5, including the step of:

providing a warning of imminent failure of said X-ray tube if f falls into a region of said classifier corresponding indicating such failure prediction.

7. A method for providing predictive maintenance of a device comprises the steps of  
5 modeling as a time series of a discretely sampled signal representative of occurrences of a defined event in the operation of said device, said time series being modeled as two-state first order Markov processes with associated transition probabilities, wherein one state applies when the number of said occurrences exceeds a certain threshold, and the other state applies when the number of said occurrences falls below said certain threshold;  
10 computing said four transition probabilities the last N states  $S_n$ , where N is a predetermined number, conducting a supervised training session utilizing a set of J devices, which have failed due to known causes and considering the two independent probabilities and, said training session comprising computing the two-dimensional feature vectors for the initial M windows of N scans, computing the two-dimensional feature vectors for the final N number of scans, plotting a scatter-diagram of all 2D feature vectors, and deriving a pattern classifier by estimating the optimal linear discriminant which separates the two foregoing sets of vectors; and applying said classifier to monitor the persistence of occurrences of said defined event in the operation of said device.  
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8. Apparatus for providing predictive maintenance of a device, comprising:

means for modeling as a time series  $x_n$  of a discretely sampled signal representative of occurrences of a defined event in the operation of said device, said time series  $x_n$  being modeled as two-state first order Markov processes with associated transition probabilities  $p(i|j)$ , wherein state 1 applies when the number of said occurrences exceeds a certain threshold T, and state 0 applies when the number of said occurrences falls below said certain threshold T , being represented as:  
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$$S_n = \begin{cases} 0 & \text{if } x_n \leq T \\ 1 & \text{if } x_n > T \end{cases}$$

wherein said transition probability  $p(i|j)$  is the switching probability from state  $j$  to state  $i$ , that is, the probability that  $S_n = i$  given that  $S_{n-1} = j$ , being a total of 4 transition probabilities;

5 means for computing said four transition probabilities the last  $N$  states  $S_n$ , where  $N$  is a predetermined number;

means for conducting a supervised training session utilizing a set of  $J$  devices, which have failed due to known causes and considering the two independent probabilities  $p(1|1)$  and  $p(1|0)$ , said means for conducting a supervised training session comprising  
10 means for:

computing the two-dimensional feature vectors  $f_i = \{p(1|1), p(1|0)\}_i$  for the initial  $M$  windows of  $N$  scans,

computing the two-dimensional feature vectors  $f_f = \{p(1|1), p(1|0)\}_f$  for the final  $N$  number of scans,

15 plotting a scatter-diagram of all 2D feature vectors  $(f_i)_n$  and  $(f_f)_n$ , ( $n = 1 \dots J$ ), and

deriving a pattern classifier by estimating the optimal linear discriminant which separates the two foregoing sets of vectors; and

means for applying said classifier to monitor the persistence of occurrences of  
20 said defined event in the operation of said device.